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RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #9

TEST PLAN FOR

UNIVERSAL ACCESS TRANSCEIVER (UAT) DATALINK PERFORMANCE TESTING OF PRE-MOPS UAT EQUIPMENT WITH JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS), DISTANCE MEASURING EQUIPMENT (DME) AND UAT PULSED RADIO FREQUENCY (RF) ENVIRONMENTS

Prepared for
RTCA SC-186 Working Group 5
Test Team

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ACRONYMS

RTCA	Radio Technical Commission for Aeronautics
ADS-B	Automatic Dependent Surveillance – Broadcast
SC-186	Special Committee 186
DoD	Department of Defense
FAA	Federal Aviation Authority
WG	Working Group
UAT	Universal Access Transceiver
DME	Distance Measuring Equipment
TACAN	Tactical Air Navigation
MSR	Message Success Rate
JTIDS	Joint Tactical Information Distribution System
MOPS	Minimum Operational Performance Standard
TIS	Traffic Information Service
ASSAP	Airborne Surveillance and Separation Assurance Processing
MASPS	Minimum Aviation System Performance Standards
nmi	Nautical Mile

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BACKGROUND

The Radio Technical Commission for Aeronautics (RTCA) has convened Special Committee 186 (SC-186) to develop operational requirements and minimum performance standards for Automatic Dependent Surveillance – Broadcast (ADS-B). Several systems are being considered for implementation of ADS-B. These include Universal Access Transceiver (UAT), 1090 Mode S Extended Squitter, and VHF Data Link Mode 4 (VDL-4). The committee is considering both airborne and ground user needs for this capability. Several active Working Groups (WG) convened by SC-186 include:

WG 1 – Operations and Implementation
WG 2 – Traffic Information Service (TIS) - B
WG 3 – 1090 MHz Minimum Operational Performance Standard (MOPS) for ADS-B
WG 4 – Application Technical Requirements
WG 5 – Universal Access Transceiver (UAT) MOPS
WG 6 – Minimum Aviation System Performance Standards (MASPS) for ADS-B. Revision A

The Department of Defense is providing support to WG 5 of SC-186. WG 5 is tasked to develop Minimum Operational Performance Standards (MOPS) for the Universal Access Transceiver (UAT). The group is taking into account items such as surveillance processing, alerts functions, algorithms and required quality of surveillance performance. They are developing recommended definitions of Required Surveillance Performance (RSP).

Based on earlier test conducted at the JSC[1], the JSC was asked to provide further bench test support to the members of WG 5 to help in the collection of data to define the expected performance of UAT in various interfering signal environments. Members of the test team include personnel from the FAA Technical Center, the FAA Washington DC, the John's Hopkins Applied Physics Lab, MITRE, and the DoD.

[1] UNIVERSAL ACCESS TRANCEIVER (UAT) DATALINK PERFORMANCE AND BIT ERROR RATE (BER) TESTING IN A DISTANCE MEASURING EQUIPMENT (DME) AND JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (JTIDS) PULSED RADIO FREQUENCY (RF) ENVIRONMENT, LABORATORY MEMORANDUM #02-770, NOVEMBER 2001

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OBJECTIVE

The objective of this test plan is to define the test approach and signal parameters required to measure the performance of UAT equipment in desired and undesired signal environments.

UAT EQUIPMENT TO BE TESTED

WG 5 is providing three Pre-MOPS UAT's and the required wire harnesses and test. One UAT receiver is configured with a receiver 3-dB bandwidth of 1.2 MHz and the other 0.8 MHz. The third UAT unit is being used as the desired signal source.

TESTING OVERVIEW

Testing will consist of measuring UAT performance parameters in an RF environment consisting of undesired signals originating from other UAT and other equipment in the RF band. WG 5 is specifying co-channel and adjacent channel signal environments in which the UAT equipment is expected to operate for inclusion in the UAT MOPS. The environments include:

1. UAT extraneous pulsed signal environments.
    a. LA – 2020 (Los Angeles - 2020) environment
    b. Core European environment

2. DME extraneous pulsed signal environments.
    a. (to be determined)

3. JTIDS/MIDS signal environments.
    a. Scenario 1 – 100/50(300) - Uncoordinated Operations L-16 Baseline
    b. Scenario 2 – 400/50 - Coordinated Operations L-16 Heavy
    c. Scenario 3 – 100/20(300) - Uncoordinated Operations L-16 Light

BENCH TEST EQUIPMENT CONFIGURATION

The two UAT receivers, the UAT transmitter and UAT undesired signal sources will be transported to the Joint Spectrum Center and configured by members of the JHU and FAA test team members. The test data collection software and PC test controller, counters, DME and JTIDS signal generating equipment as well as all RF cabling, signal attenuators and power supplies will by supplied by the JSC. Figure 2 shows the bench test setup and equipment to be used to conduct the UAT testing.

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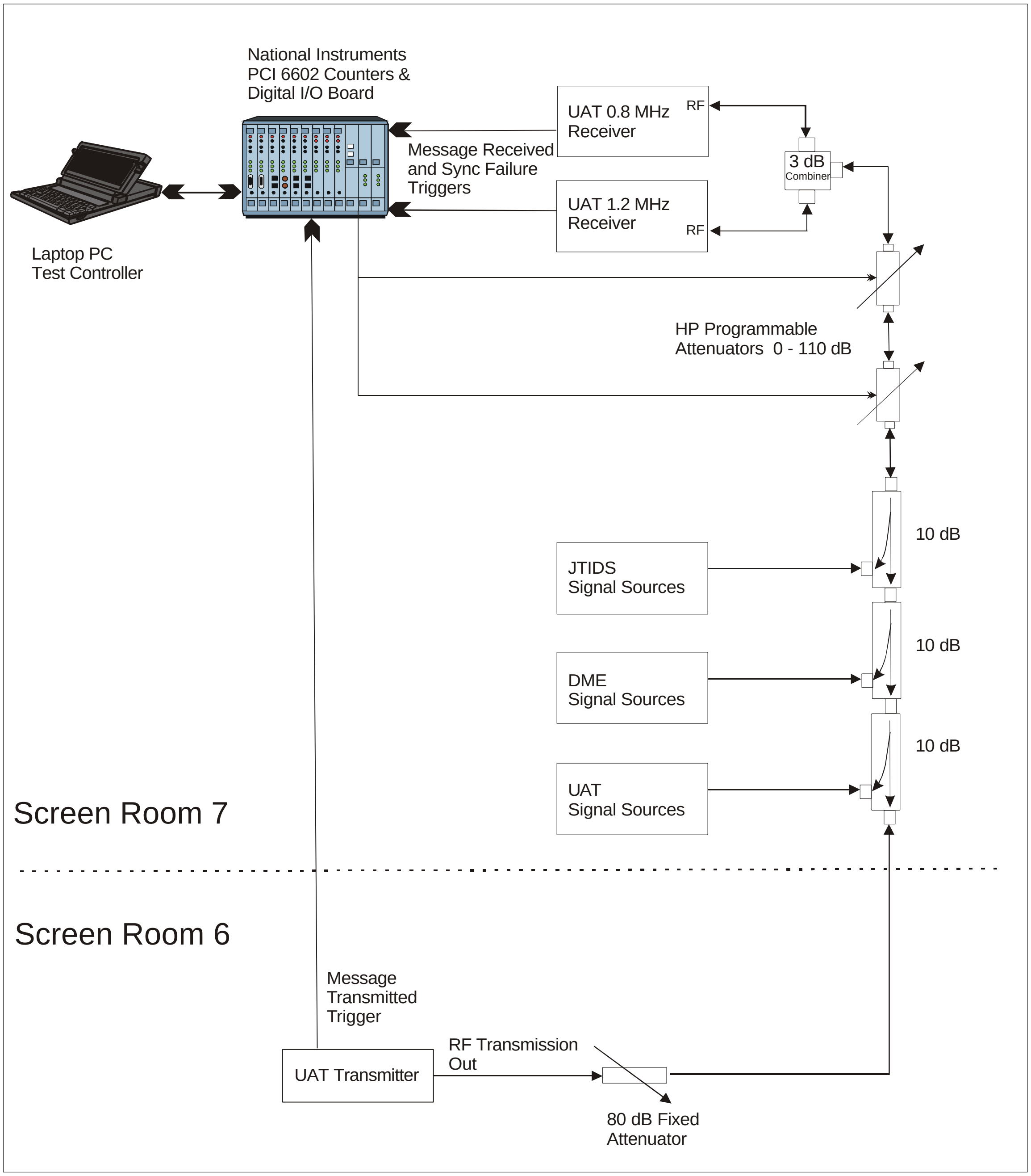

Figure 2. UAT MER Test Setup

The UAT transmitter unit will provide the desired signal source. The transmitter has been specially configured to transmit thirty-two random data bit messages per second to support UAT bench tests. A normal UAT unit transmits only one message per second with the message data defined by the information transmitted. The UAT transmitter output power will be attenuated by at least 80 dB to bring the input power closer to the receiver sensitivity levels. Additional programmable attenuation will be used to control the desired UAT transmission signal levels at the UAT receivers. The RF path losses to each UAT receiver will be calibrated so that the desired signal will arrive at both UAT receivers at the same level. It is expected that a number of desired signal levels will be used to collect the data. In particular signal levels ranging from -100, -99, ...-85 (in 1 dB steps) and then -80, -75, -60, -50 are being initially planned. Individual signal levels will be added or subtracted from this list after initial test results are evaluated to avoid collecting data in areas where minimal information can be obtained.

The transmitter and receiver units were also modified to provide a synchronous trigger output to indicate an RF transmission or reception. These "sync" signals in the receivers signify the successful reception of a UAT message. The ratio of the number of successfully received messages to the number of transmitted messages is defined as the Message Success Rate (MSR), which is a performance measure of the UAT.

To collect MSR data, the three "sync" signals from the units will be counted. Each of the inputs will be applied to a computer-controlled counter. The three counters share a common gate and will be programmed to count "sync" pulses only after the computer activates the gate signal. MSR data is collected based on 1000 transmitted samples. To achieve 1000 samples, for the air-to-air mode, the gate length will be set to 31.25 seconds (32 transmissions per second). The data collection process will occur under automated computer control to maximize time efficiency and data repeatability.

In addition to MSR, the synchronization failures of each of the units will be counted. A synchronization failure indicates the incomplete decode of a message synchronization header. The required test signal will be obtained from test points provided as an output from the UAT receiver equipment.

The data for MSR and sync failures will be collected three times for each desired signal level tested.

The undesired signals will be introduced into the desired signal path with directional signal couplers. Undesired signal sources consist of UAT signals, JTIDS Signals and DME signals. Each of the undesired signal source paths will be calibrated for line loss to the unit under test. The signal level at the source of each signal will be adjusted to provide the correct signal level at the receiver input connector.

Testing will also be accomplished without undesired signals present to measure the sensitivity of the units. The baseline sensitivity of the UAT is defined to be the received signal level at which the UAT is able to produce a reply efficiency of ninety percent.

The data will be collected by the data collection computer and stored in the form of ASCII text data files. These files will be provided as data for record test results.

UNDESIRED TEST SIGNAL DEFINITIONS

UAT Signals and Signal Source

The UAT scenarios selected were chosen from the Technical Link Assessment Team (TLAT) scenarios that were utilized to compare the performance of the three candidate links under consideration for ADS-B implementation. The scenarios involve two geographic areas, Core Europe and Los Angeles Basin. The scenarios were based on the future 2020 environment for the LA Basin and 2015 for Core Europe. The two airspace regions are quite different in character, chosen to provide two diverse views of the data link performance. The two geographical areas correspond to very different types of situations for an aircraft to operate in, and thus provide two diverse environments for evaluation. The LA Basin scenario contains only about 14% of all airborne aircraft, which are above 10000 ft in altitude, while the Core Europe scenario has around 60% above 10000 ft. Thus, there will be vastly different numbers of aircraft in view for the two scenarios. Additionally, the aircraft density distributions are also quite different, which will also place different stresses on the UAT system.

The LA Basin 2020 scenario was based on the 1999 maximum estimate and projected to the year 2020 based on a few percent increase each year. The traffic in 2020 represents a 50% increase over the 1999 LA traffic. The scenario includes a total of 2694 aircraft, 1180 within the core 225 nmi area, 1280 aircraft between 225 and 400 miles and 225 on the ground. All aircraft are assumed to be ADS-B equipped. The equipage levels are: 30 % A3, 10% A2, 40% A1, and 20% A0. The altitude distribution of the airborne aircraft was assumed to be exponential with a mean altitude of 5500 feet.

For the Core Europe 2015 scenario, the distributions and assumptions made were taken directly from the Eurocontrol document entitled “High-Density 2015 European Traffic Distributions for Simulation,” dated August 17, 1999. This scenario is fairly well-defined and straightforward to apply. This scenario includes a total of 2091 aircraft (both airborne and ground). All aircraft are assumed to be ADS-B equipped. The equipage levels have been adjusted to be around 30 % A3, 30% A2, 30% A1, and 10% A0, according to altitude. The lower percentages of A0 and A1 aircraft than those found in the LA Basin scenarios reflect differences in operating conditions and rules in European airspace.

The UAT extraneous pulse signal source is capable of providing asynchronous random transmission of UAT signals. The simulator can be programmed to provide the specific signal environments derived from scenarios of projected UAT usage. Amplitudes and UAT message types are referenced to a victim receiver selected from the scenario. The LA-2020 environment defines a UAT signal environment derived from an analysis of projected UAT air traffic in the Los Angeles Basin by the year 2020. The Core European environment defines the UAT signal environment derived by Eurocontrol from an analysis of projected European air traffic by the year 2020.

DME Signals and Signal Source

The DME extraneous pulse environment (EPE) definitions have been derived by SC-186 WG 5 from an analysis of present and planned use of DME/TACAN ground beacons. The sites considered in the analysis included the densest of those configurations planned for TACAN/DME equipment in both the USA and European channel plans. Table 1 provides the definition of the DME pulsed environment.

TABLE 1
UAT TACAN/DME EPE [a]

Relative Frequency [b] (MHz)	Beacon Type	Pulse Spacing μ Seconds	Beacon Pulse Rate (ppps)	Signal Level (dBm)
+1	TACAN	12	3600	-56
+1	DME	12	2700	-64
+1	TACAN	30	3600	-71
[a] Preliminary Findings to be updated prior to test [b] With Respect to UAT Receive Frequency				

The DME signal source is being provided by the Extraneous Pulse Source (EPS). The EPS was developed in support of a DoD test program to investigate the compatibility of JTIDS with systems operating in the 960-1215 MHz band. These systems include TACAN, DME and precision DME. The EPS is designed to simulate realistic operational environments of radio frequency signals within this band.

The EPS generates the extraneous TACAN, conventional DME (DME/N) and precision DME (DME/P) signals that would be arriving at a unit under test (UUT) operating in an aeronautical radio navigation environment. The extraneous signals can be on either a co-channel or an adjacent-channel frequency that can be produced by TACAN/DME interrogators and/or TACAN/DME beacons. The EPS can produce independent pulsed environments (multiple amplitudes, pulse-spacings, pulse rates and pulse shapes on a per channel basis) on five different TACAN/DME frequencies. The composite signal generated by the EPS is called the extraneous pulse environment (EPE).

JTIDS Signals and Signal Sources

The JTIDS signal sources are capable of being configured to transmit multiple JTIDS transmissions simultaneously. A worst-case signal environment was derived from an assumed JTIDS usage, which covers a number of theoretical scenarios. The proposed scenarios have been defined in UAT-WP4-04 found in Appendix A. Figure 1 provides a graphic that illustrates the JTIDS test scenario to be used for this testing.

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NET 0	Tx Delay 0 uSec 20 % FG	Tx Delay 0 uSec 30 % R1	Tx Delay 0 uSec 50 % R2
NET 1	Tx Delay 2600 uSec 20 % R3	Tx Delay 2600 uSec 30 % R3	Tx Delay 2600 uSec 50 % R3
NET 2	Tx Delay 3200 uSec 20 % R4	Tx Delay 3200 uSec 30 % R4	Tx Delay 3200 uSec 50 % R3
NET 3	Tx Delay 5600 uSec 20 % R4	Tx Delay 5600 uSec 30 % R4	Tx Delay 5600 uSec 50 % R4

Figure 1. UAT Link-16 Scenario

To provide the required JTIDS signal conditions, a four net scenario has been defined. Each of the nets provides simultaneous transmission of JTIDS signals using independent frequency hopping and jitter. Four JTIDS signal sources are necessary to provide the specified 400% time slot duty factor (TSDF).

Each of the blocks within the figure represent a group of timeslots over which time delay and signal level can be controlled. The designations for FG, R1, R2, R3 or R4 indicate that the JTIDS timeslots transmitted by that block can be assigned to particular signal levels and time delay. The percentage number written in any particular block represents the TSDF percentage transmitted by that block. By control of the signal level of the variously labeled blocks the desired scenario configurations described in Appendix A can be provided to the UUT.

Tables 2 through 4 summarize the JTIDS signal levels and TSDF that will be used to provide the JTIDS signal environments described in Appendix A.

Table 2. Scenario 1 – 100/50/(300) – Uncoordinated Operations JTIDS Baseline								
	FG		R2		R3		R4	
Option	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)
A	50	-53	50	-63			300	-87.5
B	50	-42	50	-63			300	-87.5
C	20	-42	30	-53	50	-63	300	-87.5

Table 3. Scenario 2 – 400/50 - Coordinated Operations JTIDS Heavy								
	FG		R2		R3		R4	
Option	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)
A	50	-42	50	-63	150	-78	150	-85
B	50	-53	50	-63	150	-78	150	-85
C	50	-63	50	-63	150	-78	150	-85

Table 4. Scenario 3 – 100/20(300) - Uncoordinated Operations JTIDS Light								
	FG		R2		R3		R4	
Option	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)	TSDF (%)	Power (dBm)
A	20	-42	80	-63			300	-93

Additional JTIDS signal levels and scenarios may be added to in to the scenarios described above.

TEST CONDITIONS

Table 5 lists the required test conditions. Testing will occur with 1 DME signal environment for all tests. The two UAT environments, the LA-2020 and Core European environment, will be tested individually without other interfering signals in addition to tests with JTIDS and DME signals. At least 7 JTIDS environments as indicated in Tables 2-4 will be used. Additional JTIDS environments may also be tested.

TABLE 5. UAT BENCH TEST MATRIX

UAT BENCH TEST MATRIX	
Test Configuration	Number of UAT Test Conditions
UAT Desired Signal Levels (dBm) (-100, -99, …-85), -80, -70, -60, -50	20
Confirmation Data point Repeats	3
Baseline Sensitivity Tests	2 (20*3*2 = 120 Data Points)
Core Europe and LA-2020 (only)	2 (20*3*2 = 120 Data Points)
Interleaving of individual undesired signals (UAT/DME/JTIDS ON/OFF – *NO Interleaving; all undesired signals always on*)	1
DME Extraneous Pulse Signal Conditions	1
UAT Mode (Air/Ground)	1 (Air Mode only)
UAT Forward Error Correction Algorithm (ON/OFF)	1 (Always ON)
UAT Extraneous Pulse Signal Conditions	2 (LA 2020 and Core European)
JTIDS – Link-16 Conditions	7
Total Number of Data Points [a]	(120 + 120) + (20*3*2*7) = 1080
[a] Deviations from the planned test procedures and interfering signal conditions will be decided during test data collection based on input received from the test team member participants. It is expected that more JTIDS/Link 16 test conditions will be added to increase the test conditions and that the number of expected desired signal levels may change.	

DOCUMENTATION

The JSC will provide a report summarizing the results of the tests to the Joint Staff and to WG5 as a working paper.

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APPENDIX A

UAT-WP-4-04
1 May 2001

RTCA Special Committee 186, Working Group 5
ADS-B UAT MOPS
Meeting #4
Link-16 Interference Environments

Prepared by Mr Michael Biggs (Federal Aviation Administration) and
LCDR Richard Weathers (Joint Chiefs of Staff)

SUMMARY

This paper presents three Link-16 interference environments against which to evaluate UAT (modified) performance. Scenarios include:

- The previously presented “Baseline” scenario (for evaluation in all UAT self interference environments)
- A “Heavy” scenario simulating major exercise activity (for evaluation in the “Low- Density” UAT self-interference environment)
- A “Light” scenario simulating a carefully controlled operation (for evaluation in the “High-Density” UAT self-interference environment)

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APPENDIX A

Scenario One (Uncoordinated Operations-L16 Baseline)

<u>Emitters: 100/50/(300)</u>

<u>Emitter 1 (Foreground)</u>

Effective Radiated Power: 200W at transmitter antenna TSDFs:
Option A: TSDF 50% at –50 dBm (1.8nm-3nm)
Option B: TSDF 50% at -39 dBm (1000 ft vertical)
Option C: TSDF 20% at -39 dBm (1000 ft vertical) and 30% at -50 dBm (1.8nm-3nm)

<u>Emitter 2 (Near Background)</u>

Effective Radiated Power: 200W at transmitter antenna
TSDF: 50% at -60 dBm (5.9nm)

<u>Emitter 3 (Far Background)</u>
Effective Radiated Power: 200W at transmitter antenna
TSDF: 300% at –84.5 dBm (100nm)

<u>Participant Dispositions:</u>

Emitters 2-3 maintain same relative disposition from “victim” receiver for duration of run.

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APPENDIX A

Scenario Two (Coordinated Operations-L16 Heavy)

Emitters: 400/50

Emitter 1 (Foreground)
Effective Radiated Power: 200W at transmitter antenna
Option A: TSDF 50% at –39 dBm (1000 ft)
Option B: TSDF 50% at –50 dBm (1.8nm-3nm)
Option C: TSDF 50% at –60 dBm (5.9nm)

Emitter 2 (Near Background)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 50% at -60 dBm (5.9nm)

Emitter 3 (Near Background)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 150% at –78 dBm (46nm)

Emitter 4 (Far Background)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 150% at –82 dBm (73nm)

Participant Dispositions:

Emitters 2-4 maintain same relative disposition from “victim” receiver for duration of each run. Second run simulates controlling relative position of nearest foreground emitter from “victim” aircraft.

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APPENDIX A

Scenario Three (Uncoordinated Operations-L16 Light)

Emitters: 100/20/(300)

Emitter 1 (Foreground)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 20% at –39 dBm (1000 ft)

Emitter 2 (Near Background)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 80% at -60 dBm (5.9nm)

Emitter 3 (Far Background)
Effective Radiated Power: 200W at transmitter antenna
TSDF: 300% at –90 dBm (200nm)

Participant Dispositions:

All emitters maintain same relative disposition from "victim" receiver for duration of run.